

What is claimed is:

1. A limit cycle autotuning method of calculating
2 a control parameter by alternately performing operation
3 of outputting a predetermined heat-side manipulated
4 variable set point to a heating actuator and operation
5 of outputting a predetermined cool-side manipulated
6 variable set point to a cooling actuator in a heat/cool
7 control apparatus which performs temperature control by
8 performing feedback control computation with respect to
9 a deviation between a set point and a controlled
10 variable on the basis of the control parameter, and
11 properly switching a heat mode of outputting a
12 manipulated variable to the heating actuator and a cool
13 mode of outputting a manipulated variable to a cooling
14 actuator, comprising:
15 the first limit cycle generation step of
16 generating a first limit cycle of alternately outputting
17 the heat-side manipulated variable set point and the
18 cool-side manipulated variable set point;
19 the first control response detection step of
20 detecting a first control response corresponding to the
21 first limit cycle;
22 the second limit cycle generation step of
23 generating a second limit cycle by changing one of the
24 heat-side manipulated variable set point and the
25 cool-side manipulated variable set point on the basis of

26 predetermined change instruction information for
27 instructing which one of the heat-side manipulated
28 variable set point and the cool-side manipulated
29 variable set point is to be changed after the first
30 limit cycle and a predetermined manipulated variable
31 change ratio indicating a degree of the change;
32 the second control response detection step of
33 detecting a second control response corresponding to the
34 second limit cycle; and
35 the control parameter calculation step of
36 calculating the control parameter for each of the heat
37 mode and the cool mode on the basis of the detected
38 first and second control responses.

2. A limit cycle autotuning method of calculating
2 a control parameter by alternately performing operation
3 of outputting a predetermined heat-side manipulated
4 variable set point to a heating actuator and operation
5 of outputting a predetermined cool-side manipulated
6 variable set point to a cooling actuator in a heat/cool
7 control apparatus which performs temperature control by
8 performing feedback control computation with respect to
9 a deviation between a set point and a controlled
10 variable on the basis of the control parameter, and
11 properly switching a heat mode of outputting a
12 manipulated variable to the heating actuator and a cool
13 mode of outputting a manipulated variable to a cooling

14 actuator, comprising:
15 the first limit cycle generation step of
16 generating a first limit cycle of alternately outputting
17 the heat-side manipulated variable set point and the
18 cool-side manipulated variable set point;
19 the first control response detection step of
20 detecting a first control response corresponding to the
21 first limit cycle;
22 the manipulated variable change ratio
23 calculation step of determining, on the basis of the
24 first control response, change instruction information
25 for instructing which one of the heat-side manipulated
26 variable set point and the cool-side manipulated
27 variable set point is to be changed after the first
28 limit cycle and a manipulated variable change ratio
29 indicating a degree of the change;
30 the second limit cycle generation step of
31 generating a second limit cycle by changing one of the
32 heat-side manipulated variable set point and the
33 cool-side manipulated variable set point on the basis of
34 the change instruction information and the manipulated
35 variable change ratio;
36 the second control response detection step of
37 detecting a second control response corresponding to the
38 second limit cycle; and
39 the control parameter calculation step of
40 calculating the control parameter for each of the heat

41 mode and the cool mode on the basis of the detected
42 first and second control responses.

3. A method according to claim 1, wherein
2 the feedback control computation includes PID
3 control computation based on the control parameter
4 including a proportional band, an integral time, and a
5 derivative time,
6 in the first control response detection step,
7 a first amplitude of a controlled variable is detected
8 as the first control response,
9 in the second control response detection step,
10 a second amplitude of a controlled variable, a heat-side
11 elapsed time from the instant at which output of a
12 manipulated variable set point is switched to a heat
13 side to the instant at which the controlled variable
14 reaches a minimum value, and a cool-side elapsed time
15 from the instant at which output of a manipulated
16 variable set point is switched to a cool side to the
17 instant at which the controlled variable reaches a
18 maximum value are detected as the second control
19 response, and
20 in the control parameter calculation step, a
21 ratio between a heat-side process gain and a cool-side
22 process gain is obtained on the basis of the first and
23 second amplitudes, the proportional band is calculated
24 for each of the heat mode and the cool mode from the

25 ratio, and the integral and derivative times common to
26 the heat mode and the cool mode are calculated from an
27 average of the heat-side elapsed time and the cool-side
28 elapsed time.

4. A method according to claim 2, wherein
2 the feedback control computation includes PID
3 control computation based on the control parameter
4 including a proportional band, an integral time, and a
5 derivative time,
6 in the first control response detection step,
7 a first amplitude of a controlled variable, a heat-side
8 maximum deviation set when the controlled variable
9 reaches a maximum value, and a cool-side maximum
10 deviation set when the controlled variable reaches a
11 minimum value are detected as the first control
12 response,
13 in the second control response detection step,
14 a second amplitude of a controlled variable, a heat-side
15 elapsed time from the instant at which output of a
16 manipulated variable set point is switched to a heat
17 side to the instant at which the controlled variable
18 reaches a minimum value, and a cool-side elapsed time
19 from the instant at which output of a manipulated
20 variable set point is switched to a cool side to the
21 instant at which the controlled variable reaches a
22 maximum value are detected as the second control

23 response,
24 in the manipulated variable change ratio
25 calculation step, the change instruction information and
26 the manipulated variable change ratio are determined on
27 the basis of the heat-side maximum deviation and the
28 cool-side maximum deviation, and
29 in the control parameter calculation step, a
30 ratio between a heat-side process gain and a cool-side
31 process gain is obtained on the basis of the first and
32 second amplitudes, the proportional band is calculated
33 for each of the heat mode and the cool mode from the
34 ratio, the integral and derivative times in the heat
35 mode are calculated from the heat-side elapsed time, and
36 the integral and derivative times in the cool mode are
37 calculated from the cool-side elapsed time.

5. A heat/cool control apparatus which has a
2 limit cycle autotuning function of calculating a control
3 parameter by alternately performing operation of
4 outputting a predetermined heat-side manipulated
5 variable set point to a heating actuator and operation
6 of outputting a predetermined cool-side manipulated
7 variable set point to a cooling actuator, and performs
8 temperature control in normal operation by properly
9 switching a heat mode of outputting a manipulated
10 variable to the heating actuator and a cool mode of
11 outputting a manipulated variable to the cooling

12 actuator, comprising:
13 control computation means for calculating a
14 manipulated variable to the heating actuator or the
15 cooling actuator by performing feedback control
16 computation with respect to a deviation between a set
17 point and a controlled variable on the basis of the
18 control parameter in the normal operation;
19 manipulated variable change ratio storage
20 means for storing in advance change instruction
21 information for instructing which one of the heat-side
22 manipulated variable set point and the cool-side
23 manipulated variable set point is to be changed during
24 the autotuning, and a manipulated variable change ratio
25 indicating a degree of the change;
26 limit cycle generating means for generating a
27 second limit cycle, during execution of the autotuning,
28 by changing one of the heat-side manipulated variable
29 set point and the cool-side manipulated variable set
30 point on the basis of the change instruction information
31 and the manipulated variable change ratio after
32 generating a first limit cycle of alternately outputting
33 the heat-side manipulated variable set point and the
34 cool-side manipulated variable set point;
35 control response detection means for detecting
36 a first control response corresponding to the first
37 limit cycle and a second control response corresponding
38 to the second limit cycle; and

39 control parameter calculation means for
40 calculating the control parameter for each of the heat
41 mode and the cool mode on the basis of the detected
42 first and second control responses, and setting the
43 calculated control parameters in said control
44 computation means.

6. An apparatus according to claim 5, comprising
2 manipulated variable change ratio calculation means for
3 determining the change instruction information and the
4 manipulated variable change ratio on the basis of the
5 first control response, in place of said manipulated
6 variable change ratio storage means.

7. An apparatus according to claim 5, wherein
2 said control computation means performs PID
3 control computation on the basis of the control
4 parameter including a proportional band, an integral
5 time, and a derivative time,
6 said control response detection means detects
7 a first amplitude of a controlled variable as the first
8 control response, and detects a second amplitude of a
9 controlled variable, a heat-side elapsed time from the
10 instant at which output of a manipulated variable set
11 point is switched to a heat side to the instant at which
12 the controlled variable reaches a minimum value, and a
13 cool-side elapsed time from the instant at which output

14 of a manipulated variable set point is switched to a
15 cool side to the instant at which the controlled
16 variable reaches a maximum value as the second control
17 response, and
18 said control parameter calculation means
19 obtains a ratio between a heat-side process gain and a
20 cool-side process gain on the basis of the first and
21 second amplitudes, calculates the proportional band for
22 each of the heat mode and the cool mode from the ratio,
23 and calculates the integral and derivative times common
24 to the heat mode and the cool mode from an average of
25 the heat-side elapsed time and the cool-side elapsed
26 time.

8. An apparatus according to claim 6, wherein
2 said control computation means performs PID
3 control computation on the basis of the control
4 parameter including a proportional band, an integral
5 time, and a derivative time,
6 said control response detection means detects
7 a first amplitude of a controlled variable, a heat-side
8 maximum deviation set when a controlled variable reaches
9 a maximum value, and a cool-side maximum deviation set
10 when a controlled variable reaches a minimum value as
11 the first control response, and detects a second
12 amplitude of a controlled variable, a heat-side elapsed
13 time from the instant at which output of a manipulated

14 variable set point is switched to a heat side to the
15 instant at which the controlled variable reaches a
16 minimum value, and a cool-side elapsed time from the
17 instant at which output of a manipulated variable set
18 point is switched to a cool side to the instant at which
19 the controlled variable reaches a maximum value as the
20 second control response,

21 said manipulated variable change ratio
22 calculation means determines the change instruction
23 information and the manipulated variable change ratio on
24 the basis of the heat-side maximum deviation and the
25 cool-side maximum deviation, and

26 said control parameter calculation means
27 obtains a ratio between a heat-side process gain and a
28 cool-side process gain on the basis of the first and
29 second amplitudes, calculates the proportional band for
30 each of the heat mode and the cool mode from the ratio,
31 calculates the integral and derivative times in the heat
32 mode from the heat-side elapsed time, and calculates the
33 integral and derivative times in the cool mode from the
34 cool-side elapsed time.